Health & Safety Manual

Supplement 33.47

LLNL Radiological Safety Program for Radiation-Generating Devices

Approved by the ES&H Working Group

_____ **date** _____

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LLNL Radiological Safety Program
for Radiation-Generating Devices*

Contents

1.0 Introduction

A radiation-generating device (RGD) is defined as a device that generates ionizing radiation either incidentally or intentionally (including accelerators.) (Appendix A contains other terms and definitions used in this supplement.)

This supplement specifies the relevant radiological safety requirements for all RGDs, except medical x-ray devices and gamma irradiation containing large, sealed sources. Medical x-ray devices used for diagnostic purposes shall comply with safety requirements specified by the Food and Drug Administration. Safety requirements for the use and storage of sealed sources are specified in Chapter 33, Section 33.45 (Handling of Sealed Radioactive Sources) and Section 33.49 (Gamma-Ray Installations), of the *Health & Safety Manual.*

Further exceptions to the requirements of this supplement require concurrence of the health physics technical leader (or designee) and RGD operator and authorization by line management. Both major (e.g., bypassing of interlocks) and minor (e.g., small changes in safety procedures) exceptions are to be reviewed by the environmental, safety, and health (ES&H) team health physicist. In addition, the appropriate documentation shall be prepared (see Table 1 below).

Table 1. Documentation required for exceptions to requirements.

IF exception is	THEN, prepare
Major	**1. An OSP or FSP for normal operation,** **OR** **2. An ES&H Integrated Worksheet for maintenance/repair. (See Chapter 2 of the Manual for a copy of the worksheet and Section 4.2 of this supplement for further details on maintenance.)**
Minor	**An ES&H Integrated Worksheet for both normal operations and maintenance/repair.**

2.0 Applicability

This supplement applies to all RGDs (except medical x-ray devices) operated at LLNL and to LLNL-managed RGD operations at remote locations, including maintenance work performed by factory-authorized representatives or LLNL maintenance personnel.

3.0 Requirements/Regulatory Summary

Occupational radiation safety requirements are specified in 10 CFR 835 and in Supplement 33.02 (Occupational Radiation Protection–Implementation of 10 CFR 835) of the *Health & Safety Manual*. DOE Order 5480.25 applies to facilities at LLNL identified as accelerators. Guidance has been incorporated into this document wherever feasible from ANSI N43.3, "Installations Using Non-Medical X-Ray and Sealed Gamma-Ray Sources, Energies Up To 10 MeV"; ANSI N43.2, "Radiation Safety For X-Ray Diffraction and Fluorescence Analysis Equipment"; and ANSI N43.1, "Radiological Safety in the Design and Operation of Particle Accelerators."

4.0 The RGD Radiological Safety Program

Safety requirements for RGDs depend on the operational status of the device, which may be any of the following:

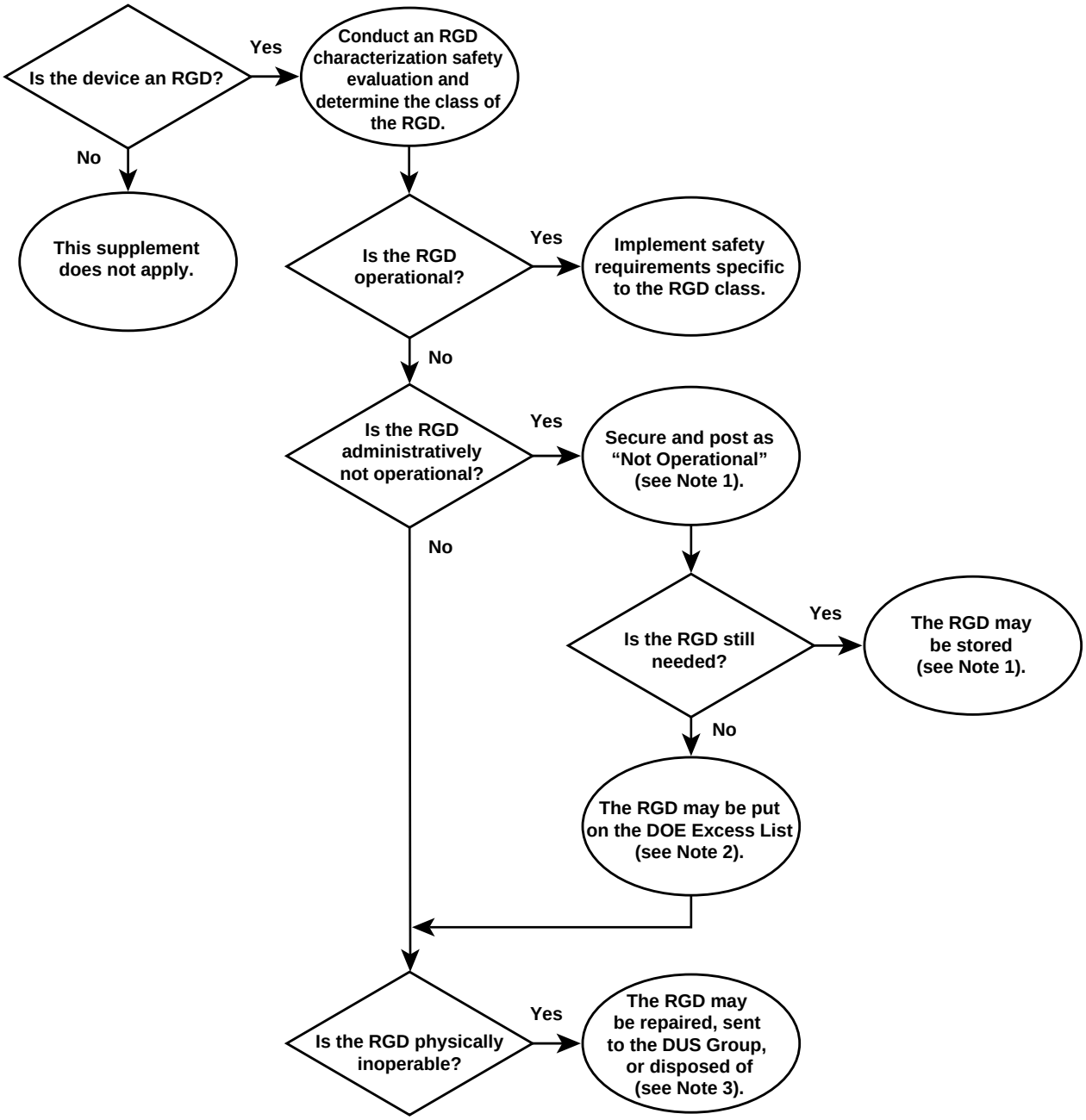
- **Operational**—Device is functionally and administratively operational.
- **Not Operational**—Device is administratively not operational.
- **Transferred, Excessed, or Salvaged**—Device has been removed from LLNL, has been excessed, or has been partially or fully disassembled such that it cannot be operated without major repair by a qualified technician.

The process for implementing the RGD Radiological Safety Program is fully described in the following sections. A flowchart outlining the relevant radiation protection requirements for RGDs is shown in Figure 1.

4.1 Identifying RGDs

RGDs include the following:

- **Devices that produce x-rays incidentally.** These may include electron microscopes, high-voltage electron guns, electron arc-welding



Note 1: An annual inventory is required, but a radiation survey is NOT required.
Note 2: Complete an Equipment/Property Release Form and obtain the ES&H team health physicist's signature.
Note 3: Notify the ES&H team health physicist.

Figure 1. Flowchart to determine relevant radiation protection requirements for RGDs.

machines, and electron beam devices with energies >5 kV. Incidental devices exempt from the requirements of this supplement are

  — Unmodified commercially available incidental radiation-generating devices with energies ≤15 kV that produce no significant radiation fields above background when measured 5 cm (2 in.) from the device surface (or at the closest accessible surface) and when operated at the maximum approved operating parameters. Examples of devices that *may* fit into this category are high-voltage switches and power supplies containing various types of thermionic valves installed in shielded cabinets or racks, mass spectrometers, vacuum switches, and spark-gap devices. Devices should be characterized to determine if they fit into this category.
  — Commercially available electronic components such as cathode-ray tubes (i.e., computer monitors and televisions).

- **Devices that produce ionizing radiation intentionally**. These may include x-ray diffraction and fluorescence analysis systems, flash x-ray machines, cabinet x-ray machines, industrial radiography equipment, and accelerators. See Appendix A for a listing of devices classified as accelerators at the LLNL.

4.2 Managing RGDs at LLNL

Procurement and RGD Facility Design. Hazards Control must approve all purchase orders for new RGDs, or the acquisition of RGDs from other institutions, and shall review the design of new RGD facilities. An initial characterization is required for each new device, as specified in Section 4.3.

Maintenance. Plans for either LLNL maintenance personnel or authorized factory representatives to perform maintenance and repair work that can modify the safety systems on RGDs must be discussed with the ES&H team health physicist prior to beginning work. The ES&H team health physicist shall use the ES&H Integrated Worksheet to document any limitations required. LLNL personnel (including students, contractors, and visitors) shall not physically participate in any operation that is outside of accepted LLNL procedures. The RGD operator shall document all maintenance and repair of the RGD. A radiation survey shall be conducted following maintenance or repair that involves disassembly of the x-ray tube, tube housing, shutters, or shielding before resuming LLNL operations. If the device has been modified significantly, a re-characterization by a health physicist is required.

Transfer or Movement of RGDs. To ensure compliance with all applicable radiation protection regulations, the operator or responsible person shall

- Notify the ES&H team health physicist or health and safety technician prior to (1) relocating an RGD, (2) administratively transferring an RGD either onsite or to any offsite location, or (3) transferring an RGD to the DOE Excess List.

- Complete and have the ES&H team health physicist sign the Equipment/Property Release Form for planned transfers of RGDs to *non-LLNL* individuals or institutions. (NOTE: RGDs may only be transferred to appropriately authorized individuals or institutions, as determined by the RGD safety officer.)
- Ensure the RGD is labeled as capable of producing x-rays.

"Not Operational" RGDs and Storage. Usable RGDs that are no longer needed, but are still capable of producing x-rays, may be posted as "Not Operational" and left in place or sent to equipment storage. The RGD posting indicating that the device generates x-rays must remain in place.

Disposal of RGDs. Only RGDs that have been rendered non-functional (i.e., broken beyond repair) may be transferred to the Donation, Utilization, and Sales (DUS) Group or disposed of in a municipal landfill. All RGD transfers to the DUS Group or to a municipal landfill shall be authorized by the ES&H team health physicist. Decommissioning or dismantling of accelerators or other large devices shall be handled on a case-by-case basis.

4.3 Conducting RGD Characterization/Radiation Safety Evaluations

RGDs (including all x-ray ports and tubes) must have an initial characterization and a radiation safety evaluation, which should include input from both the operator and the ES&H team health physicist, in order to identify the potential hazards. The evaluation shall be phased in for existing RGDs at the next expected survey, completed before use of new devices, and repeated whenever the maximum operating parameters change. A re-evaluation also may be required following maintenance or repair of an RGD, as discussed in Section 4.2.

The RGD characterization and radiation safety evaluation are conducted to assess

- The capabilities of the device.
- The radiation intensity involved under maximum approved operating parameters.
- The inherent safety devices associated with the machine.
- Associated operating procedures.
- Potential doses from accidental exposures resulting from failure of the most likely single component or procedure. Based on these potential doses, the ES&H team health physicist shall specify the appropriate RGD classification (Class I, II, III, or IV. See section 4.4 for details.). If further safety requirements are needed to assure safe operations, the health physicist may classify the device into a higher risk category.

Evaluations shall be documented on the RGD Characterization/Radiation Safety Evaluation Form. A copy of the completed form shall be kept in the RGD logbook (if applicable) or with the device operator, and a copy shall be sent to the RGD safety officer for concurrence and long-term record storage. (Macintosh users: For a copy of this form, open the Chooser, select the HC AppleTalk Zone, select AppleShare, then select the fileserver "Health & Safety" and click OK. Log on as "guest," then select the "H&S info" folder. The folder will appear on your desktop. Double-click to open, then open the folder labeled "Health Physics." The RGD Characterization/Radiation Safety Evaluation Form is located in the folder labeled "RDG Current Inventory/Forms.").

4.4 Classifying RGDs

RGDs are classified by the ES&H team health physicist into one of four categories (Class I, II, III, or IV) based on the potential risk of extremity, eye, or whole-body exposure.

4.4.1 Class I Devices

These devices are incapable of reasonably producing an accidental dose >100 mrem/y to *either* a localized area of the body (e.g., an eye or a finger) or to the whole body.

Class I devices are designed by the manufacturer to be inherently safe. These devices include shielding and/or design features that permit operation without requiring significant occupancy controls or personnel in attendance. The dose should not be >0.5 mrem/h when measured at 5 cm (2 in.) from the surface of the enclosure or be capable of reasonably exposing a person to localized or whole-body doses >100 mrem/y. If the RGD is modified from its original design, it shall be re-characterized to validate that the integral safety features have not been compromised. Examples of devices that *may* fit into this class are vacuum-plating units, electron microscopes, high-voltage rectifiers, some electron-beam welders, and cabinet x-ray systems certified in accordance with 21 CFR 1020.40. ANSI's "Exempt Shielded Installations" category typically would fit into this category.

4.4.2 Class II Devices

These devices are capable of reasonably producing accidental whole-body doses between 0.1 and 15 rem, extremity doses between 0.1 and 150 rem, or eye doses between 0.1 and 45 rem.

Class II devices can reasonably produce up to three times the occupational annual dose limit to the whole body, extremities, or eyes, but are not likely to produce severe biological effects. The primary beam of Class II RGDs may be inaccessible without disassembling the unit, enclosed during normal operations, or in an open-beam configuration. A secondary beam may be generated by diffraction or fluorescence and may be inaccessible, enclosed, or in an open-beam configuration. Interlocks are installed on these devices to prevent access during

normal operation. The dose rate should be <0.5 mrem/h when measured at 30 cm (12 in.) from outside the enclosure. Examples of devices that *may* fit into this class are low-intensity flash x-ray devices, radiographic x-ray devices, e-beam devices, and diffraction or fluorescence devices. ANSI's "Shielded Installations" category typically would either fit into this category or in Class III.

4.4.3 Class III Devices

These devices are capable of reasonably producing an accidental extremity dose >150 rem or an eye dose >45 rem.

Class III devices can reasonably produce more than three times the occupational annual dose limit to the extremities or the eyes, and may be capable of producing severe biological effects to localized areas of the body. These devices are unlikely to produce lethal doses of radiation due to the limited area of exposure. The primary beam of Class III RGDs may be inaccessible without disassembling the unit, enclosed during normal operations, or in an open-beam configuration. A secondary beam may be generated by diffraction or fluorescence and may be inaccessible, enclosed, or in an open-beam configuration. Interlocks are installed on these devices to prevent access during normal operation. The dose rate should be <0.5 mrem/h when measured at 30 cm (12 in.) from outside the enclosure. Examples of devices that *may* fit into this class are flash x-ray devices, radiographic x-ray devices, e-beam devices, and diffraction or fluorescence devices. ANSI's "Shielded Installations" category typically would fit into this category or in Class II.

4.4.4 Class IV Devices

These devices are capable of reasonably producing an accidental *whole-body* dose >15 rem.

Class IV devices can reasonably produce more than three times the occupational annual dose limit to the whole body, and may be capable of producing lethal levels of radiation. Radiation shielding for Class IV devices should be designed to limit personnel doses to less than one-tenth the maximum annual permissible dose (i.e., <500 mrem/y). Accelerators (as defined in LLNL's Implementation Plan for DOE Order 5480.25) shall be classified as Class IV devices and shall meet the program safety requirements of the plan. Examples of Class IV devices *may* include radiographic devices and particle accelerators.

4.4.5 Summary of Classifications

As summarized in Table 2 on the following page, the most restrictive dose is used to determine an RGD's class. For example, if an RGD is capable of producing 100 rem to an extremity and 50 rem to the eye in a reasonable accidental exposure, but is incapable of producing a whole-body dose, the RGD is a Class III device. If the RGD is capable of producing 20 rem to the whole body, it is a Class IV device regardless of the potential for extremity or eye exposure.

Table 2. Dose guidelines for RGD classification at LLNL.

Organ	Maximum dose (rem/yr)			
	Class I	Class II	Class III	Class IV
Extremity	0.1	150	>150	—
Eye	0.1	45	>45	—
Whole body	0.1	15	—	>15

4.5 Safety Requirements

Safety requirements for Class I, II, III, and IV RGDs are presented in the following sections and summarized in Appendix B. More details on these requirements can be found in Chapter 11, "Access Control, Safety Signs, and Alarm Systems," and Supplement 11.07, "Personnel Safety Interlocks," of the *Health & Safety Manual.*

4.5.1 Class I Devices

RGD Inventory. Each device is assigned a unique RGD number and an inventory is conducted at least annually. If deemed appropriate by the ES&H team health physicist, Class I devices may be inventoried by verbally contacting the device operator.

Postings. A "CAUTION. Radiation-Generating Device—Approved Operating Parameters" label shall be posted on the device console or other appropriate location.

A "Date Surveyed and Next Survey Due" sticker shall be attached to the device console or other appropriate location.

NOTE: A "Caution. X-Ray Area" sign is not required at entrances to rooms containing only Class I devices. Similarly, a "Notice. Access Control" sign is not required at the entrances to buildings housing only these devices.

Interlocks and Warning Lights. Interlocks installed by the manufacturer shall not be disabled or modified. The key for key-controlled consoles shall be removed and secured when the device is not in operation or is left unattended. Use of interlock bypass features (including those installed by the manufacturer) must be documented in a safety procedure (FSP or OSP).

Warning lights installed by the manufacturer, such as an "X-Ray On" light, shall not be modified without prior approval of the ES&H team health physicist.

Shielding and Radiation Safety Survey. The RGD shall be adequately shielded, including viewing access ports and utility penetrations. Shielding installed by the manufacturer shall not be modified without prior approval of the ES&H team health physicist.

A radiation safety survey shall be conducted by Hazards Control and the device operator at least *annually* for each Class I device, and the result shall be documented on the RGD Radiological Safety Survey Form. A survey is required sooner than one year if the RGD is modified and if the location or the maximum approved operating parameters are changed. The ES&H team health physicist may reduce the Class I annual radiation safety survey requirement to an annual verbal inventory, if the hazards associated with the device are minimal and the reduced requirement is noted on the Characterization/Radiation Safety Evaluation Form.

The ES&H team health physicist shall review completed RGD radiation safety surveys. The completed RGD Radiological Safety Survey Form shall be filed with the RGD operator and a copy shall be forwarded to the RGD safety officer for permanent recordkeeping. (Macintosh users: For a copy of this form, open the Chooser, select the HC AppleTalk Zone, select AppleShare, then select the fileserver "Health & Safety" and click OK. Log on as "guest," then select the "H&S info" folder. The folder will appear on your desktop. Double-click to open, then open the folder labeled "Health Physics." The Class I RGD Radiological Safety Survey Form is located in the folder labeled "RDG Current Inventory/Forms.")

The radiation safety survey for Class I RGDs shall include a review of the following, as appropriate:

- Approved operators.
- Device location.
- Operating parameters.
- Postings.
- Device warning indicators.
- Interlock tests (if feasible).
- Dose rate measurements 5 cm (2 in.) from the enclosure at the maximum approved operating parameters. (NOTE: The dose rate should not be >0.5 mrem/h or be capable of credibly exposing a person to a localized or whole-body dose >100 mrem/y.)

Documentation. The operator of each Class I device should maintain copies of the current RGD Characterization/Radiation Safety Evaluation Form and the most recent Radiological Safety Survey Form. A formal logbook is not required.

Training. The Hazard Information Sheet provided by the RGD safety officer shall be posted next to the device.

Other Requirements. No special monitoring equipment is required. Whole-body dosimeters shall be worn by operators, but extremity dosimetry is not required.

4.5.2 Class II and III Devices

RGD Inventory. Each device shall be assigned a unique RGD number. An inventory shall be conducted *annually* for Class II devices and *semiannually* for Class III devices.

Postings. A "Notice. Access Control Area" sign shall be posted at the entrance to the building, room, or area containing the RGD.

A "Caution. X-Ray Area" sign shall be posted at entrances to rooms or areas containing these devices.

"Radiation Area" (>5 mrem/h) or "High Radiation Area" (>100 mrem/h) signs shall also be posted at the access point, if applicable.

A "CAUTION. Radiation-Generating Device—Approved Operating Parameters" label shall be posted on the device console or other appropriate location.

A "CAUTION. Radiation-Generating Device" label shall be posted close to the port on each tube housing, if feasible.

A "Date Surveyed and Next Survey Due" sticker shall be attached to the device console or other appropriate location.

Interlocks

- The key for key-controlled consoles should be removed and secured when the device is not in use or is left unattended. Exceptions must be documented in a safety procedure (FSP or OSP).
- Fail-safe interlocks shall be used on protective enclosures.
- Enclosures to flash x-ray machines shall be interlocked to prevent entry while the high-voltage system is charged (or is being charged). When the interlock is opened, the high-voltage shall be automatically grounded.
- Rooms or other facilities used as x-ray enclosures shall have an emergency shut-down switch if a person could, in a reasonable accident scenario, become trapped in the room when the x-ray beam is on.
- Written interlock test procedures shall be established for each device and used during the radiological safety survey.
- Use of interlock bypass devices (e.g. jumpers or key switches) or other interlock bypass operations shall be documented in a safety procedure and approved in writing by line management.

Warning Lights

- Fail-safe warning lights shall be installed near the x-ray source to indicate when x-rays are being generated or when a flash x-ray system is charged (or is being charged). E-beam devices should have a fail-safe warning light installed in close proximity to the source to indicate when the machine is on.

- A fail-safe light displaying "X-Ray On" shall be located near the switch that energizes the x-ray tube. The light on the control console of flash x-ray machines shall indicate their charging status.
- RGDs with shutters should have fail-safe "Shutter Open" lights mounted near the shutters to indicate the machines' status.

Alarms

- Installation of either an x-ray monitor (LEA-92-1920) or x-ray safety box (LEA-83-1659-00), or equivalent fixed radiation detector with an alarm, should be installed if *any* of the following conditions exists:
  - Primary beam is accessible.
  - Shielding can be easily removed.
  - Interlocks can be bypassed easily.
  - The radiation safety evaluation determines that installing a safety monitor or safety box could prevent an inadvertent exposure.

  NOTE: The x-ray monitor is not effective in a pulsed radiation field.

Fixed monitors are not required for instruments where the beam is accessible only for small distances and a monitor would interfere with its operation.

Shielding for Enclosed-Beam Operations. The requirements for these operations are as follows:

- Shielding (or other commensurate positive control method) shall be installed to reduce the dose to personnel operating the equipment or occupying the area adjacent to the RGD.
- Dose rates in areas that people can occupy during RGD operation should be <0.5 mrem/h when measured at 30 cm (12 in.) from outside the enclosure.
- Beams with exposure rates >0.1 R/h should be fully enclosed, when feasible.
- All beam ports shall be covered with a radiation shield when not in use.

Shielding for Open-Beam Operations. These operations (i.e., those involving RGDs that cannot be provided with fixed shielding) shall have a documented safety procedure that includes

- A defined, posted perimeter that identifies the area where the dose equivalent rate may be >5 mrem in any one hour. A "Radiation Area" sign may be posted at the boundary of the non-controlled area, which typically is established so that an individual may not be exposed to dose equivalent rates >2 mrem in any one hour.
- A defined, posted perimeter that identifies the area where the dose equivalent rate may be >100 mrem/h. A "High Radiation Area" sign shall be posted in such areas.

- A defined, posted perimeter that identifies the area where the dose equivalent rate may be >500 rads/hr. A "Very High Radiation Area" sign shall be posted in such areas. Additional control measures (e.g., interlocked "photoelectric eye" light beams) should be installed to prevent entry into such areas.
- Provisions for a trained operator to provide surveillance in order to prevent access to areas within the posted perimeter.
- Physical or administrative controls that prevent the operator from remaining inside the posted perimeter during irradiation.
- Provisions for storing the RGD in a locked enclosure when not in use.
- Provisions that require device operators to use a survey meter to verify that radiation is no longer being produced before entering a potential "High Radiation Area" or "Very High Radiation Area" after device operation.

NOTE: Controls shall not prevent the rapid evacuation of personnel from a potentially "High Radiation Area" or "Very High Radiation Area."

Radiation Safety Survey. A radiation safety survey shall be conducted by Hazards Control and the device operator at least *annually* for Class II devices and at least *semiannually* for Class III devices, and the results shall be documented on a RGD Radiological Safety Survey Form. A radiation safety survey is required sooner than the specified frequency if the RGD is modified or the location or maximum approved operating parameters are changed. The ES&H team health physicist shall review RGD radiation safety surveys. The completed RGD Radiological Safety Survey Form shall be filed with the RGD operator and a copy shall be forwarded to the RGD safety officer for permanent recordkeeping. (Macintosh users: For a copy of this form, open the Chooser, select the HC AppleTalk Zone, select AppleShare, then select the fileserver "Health & Safety" and click OK. Log on as "guest," then select the "H&S info" folder. The folder will appear on your desktop. Double-click to open, then open the folder labeled "Health Physics." The Class II and III RGD Radiological Safety Survey Forms are located in the folder labeled "RDG Current Inventory/Forms.")

The radiation safety survey shall include a review of the following, as appropriate:

- Approved operators.
- Dosimetry exchange cycle.
- Device location.
- Operating parameters.
- Postings.
- Device warning indicators.
- Interlock tests.

- Measurement of the radiation fields at 30 cm (12 in.) from the enclosure at maximum approved operating parameters. (NOTE: The dose in occupied areas should be <0.5 mrem/h when measured at 30 cm (12 in.) from the outside of the enclosure.)

Documentation. Each Class II and Class III device shall have a safety procedure and an RGD logbook, which shall be kept near the control console. The RGD logbook should contain the following documents or reference where they can be easily found.

- A current RGD Characterization/Radiation Safety Evaluation Form.
- A current RGD Radiological Safety Survey Form.
- Written interlock test procedures.
- Maintenance records.
- Pertinent RGD correspondence, including a copy of the safety procedure and ES&H Integrated Worksheet documenting exceptions to the requirements.

Training. All users of Class II and Class III RGDs and personnel working in close proximity to these devices shall complete course HS6070, "Safety and the X-Ray Machine." Individuals working with or in close proximity to e-beam devices shall complete course HS6071, "X-Ray Safety of E-Beam Devices." Retraining is required every 24 months and can be met by completing course HS6070-R or HS6071-R.

Other Requirements. The following other requirements apply to Class II and Class III devices:

- ***Dosimetry.*** Whole-body dosimeters shall be worn by personnel who work in close proximity to Class II and Class III RGDs and shall be exchanged on a monthly basis, unless otherwise specified by the ES&H team health physicist. A supplemental dosimeter capable of immediate readout is required to access "High Radiation Areas." Extremity dosimetry (e.g., finger rings or wrist dosimeters) shall also be worn if required by the ES&H team health physicist. Specific operations that might warrant the use of extremity dosimeters include
  - — Sample changing.
  - — Target changing.
  - — Interlock bypass operations.
  - — Beam alignment.
  - — Open-beam operations.
- ***Portable Survey Meter.*** An appropriate portable radiation survey instrument shall be available for use during operation of the device.

4.5.3 Class IV Devices

Not all Class IV devices require the same physical and administrative safety controls. However, certain minimum safety standards must be established for all facilities. The following controls are for fixed facilities and may not be appropriate for short-term or temporary operations (e.g., field radiography). Other procedures that provide a commensurate level of safety may be substituted if explicitly included in an approved safety procedure. Accelerators, as defined in this supplement, shall be classified as Class IV devices and shall meet the requirements in LLNL's Implementation Plan for DOE Order 5480.25.

NOTE: As used in this supplement, "exclusion area" means any area where a person could receive an effective dose equivalent >5 rem in one hour at 1 m from the source under normal operating conditions.

RGD Inventory. Each device shall be assigned a unique RGD number, and an inventory shall be conducted at least *semiannually*.

Posting. A "Notice. Access Control Area" sign shall be posted on the building, room, or area containing the RGD.

A "Radiation Area" (>5 mrem/h), "High Radiation Area" (>100 mrem/h), or "Very High Radiation Area" (>500 rads/h) sign shall be posted at applicable access points.

A "CAUTION. Radiation-Generating Device—Approved Operating Parameters" sign shall be posted on the console.

A "CAUTION. Radiation-Generating Device" label shall be posted close to the port on each tube housing, if feasible.

A "Date Surveyed and Next Survey Due" sticker shall be attached to the device console or other appropriate location.

Interlocks

- The master key for the control console shall be the only key that allows access to exclusion areas. The control console shall be interlocked so that removal of this key will interrupt the high-voltage supply.
- Written interlock test procedures shall be established for each Class IV device.
- All personnel safety interlocks and safety systems for Class IV RGDs shall be tested at least every 6 months. Tests shall be performed jointly by the device operator and the ES&H team health physicist (or designee). Verification of the tests shall be entered into the RGD logbook.
- All interlock bypass operations shall be authorized by an approved safety procedure. All interlock bypasses shall be designed to assure that they are only temporary, and shall be conspicuously indicated on the control console and at the interlock location. The time the bypass is

turned on and off as well as the reason for the bypass shall be entered into the RGD logbook.

- Access gates or doors to exclusion areas shall be interlocked so that when the gates or doors are opened, the high-voltage supply to the device is interrupted. Redundant interlock chains or pairs of interlock switches on the same door shall be installed. See Supplement 11.07 of the *Health & Safety Manual* for more details.
- Hazard-safe (run-safe) switches or boxes capable of interrupting the high-voltage supply shall be located near entrances to exclusion areas and in exclusion areas where work could be performed. Upon entering an area equipped with hazard-safe switches, personnel shall set at least one switch to the safe position, unless this occurs automatically.
- Key-lock watchman stations (or run-safe boxes) shall be placed in strategic positions within the exclusion area to guarantee that all locations within the area have been inspected prior to operation. Before starting up a Class IV device, the operator shall perform a rigorous sweep of all potentially "High Radiation Areas" or "Very High Radiation Areas." Exceptions to requiring key-watchman stations can be made if the exclusion area is small and visibility is unimpeded. Opening any entry to an area shall necessitate manually resetting all watchman stations in that area. RGD operation shall be impossible unless all watchman stations are reset with either the master key or a key that is always on the master ring. If an individual could enter the area during the inspection without being seen, a key-lock watchman station with a timer shall be installed such that the inspection must be completed within a specified time period.
- Device operators must go to the tripped personnel safety interlock to reset it; personnel safety interlocks must not be capable of being reset from the operator's console. The master key shall be necessary for resetting the controls at an exclusion area door interlock. Interlocks shall not be used to turn off an RGD, except in an emergency.

NOTE: Controls shall not prevent the rapid evacuation of personnel from a "High Radiation Area" or Very High Radiation Area."

Warning Indicators

- Lights and Announcements
  - — Approximately 60 seconds prior to operating an RGD in large exclusion areas, the lights shall be dimmed and an audible voice or taped announcement shall state that the device is about to be operated. Personnel will also be instructed to immediately use the hazard-safe (run-safe) switches and leave the area. For open-beam operations where this requirement is not feasible, or for small exclusion areas where it is not possible for a person to be present or

know that the device is about to be operated, it is not required to dim the lights or have a voice announcement.
  - Entrances to "High Radiation Areas" and exclusion areas shall be equipped with flashing or rotating magenta lights that operate automatically whenever a Class IV device is in use.

- Alarms
  - A remote area monitor (RAM) system should be installed in all potentially "High Radiation Areas" to alert personnel to radiation levels before entry. Each RAM should have a remote and local readout, with visible and audible alarms at both the control panel and the monitored locations. The visible alarm at the monitored location shall be a rotating magenta light. Each RAM shall be checked for radiation response and calibrated annually.
  - The sounds of alarms for all Class IV devices should be consistent so that personnel can immediately recognize each sound's meaning. Class IV devices produce chimes when radiation is generated, and evacuation alarms produce a high-pitched noise.

Shielding. Shielding shall be installed to reduce the dose to personnel operating the equipment or occupying the area adjacent to the RGD. Radiation shielding should be designed to limit personnel doses to no more than one-tenth the maximum annual permissible dose (i.e., <500 mrem/y).

Open-beam operations (i.e., those involving RGDs that cannot be provided with fixed shielding) shall have documented safety procedures that include

- A defined, posted perimeter that identifies the area where the dose equivalent rate may be >5 mrem in any one hour. A "Radiation Area" sign may be posted at the boundary of the non-controlled area, which typically is established so that an individual may not be exposed to dose equivalent rates >2 mrem in any one hour.
- A defined, posted perimeter that identifies the area where the dose equivalent rate may be >100 mrem/h. A "High Radiation Area" sign shall be posted in such areas.
- A defined, posted perimeter that identifies the area where the dose equivalent rate may be >500 rads/hr. A "Very High Radiation Area" sign shall be posted in such areas. Such perimeters are determined by calculation rather than direct measurement. Additional control measures (e.g., interlocked "photoelectric eye" light beams) should be installed to prevent entry to such areas.
- Provisions for a trained operator to provide surveillance in order to prevent access to areas within the posted perimeter.
- Physical or administrative controls that prevent the operator from remaining inside the posted perimeter during RGD operation.
- Provisions for storing the RGD in a locked enclosure when not in use.

- Provisions requiring device operators to use a survey meter to verify that radiation is no longer being produced after irradiation before entering a "High Radiation Area" or "Very High Radiation Area."

NOTE: Controls shall not prevent the rapid evacuation of personnel from a potentially "High Radiation Area" or "Very High Radiation Area."

Radiation Safety Survey. A radiation safety survey shall be conducted by Hazards Control and the device operator at least *semiannually* for each Class IV device, and the result shall be documented on the RGD Radiological Safety Survey Form. A radiation safety survey is required sooner than 6 months if the machine is modified, the location or operating parameters are changed, or if specified in the safety procedure. The ES&H team health physicist shall review RGD safety surveys. The completed RGD Radiological Safety Survey Form shall be filed with the RGD operator and a copy shall be forwarded to the RGD safety officer for permanent recordkeeping. (Macintosh users: For a copy of this form, open the Chooser, select the HC AppleTalk Zone, select AppleShare, then select the fileserver "Health & Safety" and click OK. Log on as "guest," then select the "H&S info" folder. The folder will appear on your desktop. Double-click to open, then open the folder labeled "Health Physics." The Class IV RGD Radiological Safety Survey Form is located in the folder labeled "RDG Current Inventory/Forms.")

The radiation safety survey shall include a review of the following, as appropriate:

- Approved operator.
- Dosimetry exchange cycle.
- Device location.
- Operating parameters.
- Posting.
- Device warning indicators.
- Interlock testing.
- Measurement of the radiation fields from the device at the maximum approved operating parameters in potentially occupied areas.

Documentation. Each Class IV device must have a document that lists, by name, those individuals responsible for the safety of the device and all persons approved to operate the device. In addition, each device shall have an RGD logbook, which shall be kept near the control console. The RDG logbook should contain the following documents or reference where they can be found:

- A use log indicating the date, time, operator, and a description of the device's use (alternative documentation methods may be outlined in the FSP or OSP).
- A current RGD Characterization/Radiation Safety Evaluation Form.

- A current RGD Radiological Safety Survey Form.
- Written interlock test procedures.
- Maintenance records.
- Pertinent RGD correspondence, including a copy of the safety procedure (FSP or OSP) and ES&H Integrated Worksheet documenting exceptions to the requirements.
- LLNL's Implementation Plan for DOE Order 5480.25 (for all accelerators, as defined in this supplement.)

Training. All users of Class IV devices and personnel working in close proximity to these devices shall complete course HS6070, "Safety and the X-Ray Machine." Individuals working with or in close proximity to accelerators must complete course HS6911, "Radiological Worker Training for Accelerator Facilities." Retraining is required every 24 months and can be met by completing course HS6070-R or HS6911-R. Individuals who operate or work in close proximity to other RGDs (Class II, III, or IV), including accelerators, must attend both accelerator training as well as other applicable classes.

Other Requirements. The following requirements also apply to Class IV devices:

- ***Radiation Effluent Monitors***. Radiation effluent monitoring may be required if significant air, gas, or dust activation is expected as a by-product of operating a Class IV RGD. Hazards Control shall assist in determining when effluent monitoring is required and the type of monitoring to be performed.
- ***Activation Products***. Class IV devices may cause metal objects, tools, or shielding that are in close proximity to the radiation source to become activated. Items removed from exclusion areas where such activation is likely shall be surveyed for radioactivity prior to their release and handled appropriately.
- ***Dosimetry.*** All operators, experimenters, and RGD maintenance personnel shall wear a whole-body dosimeter and exchange it on a monthly basis, unless otherwise specified by the ES&H team health physicist. Neutron dosimetry may be required if neutron exposure is anticipated. Extremity dosimetry (finger rings and/or wrist dosimeter) shall be worn as required by the ES&H team health physicist.
- ***Personnel Radiation Monitors.*** A supplemental dosimeter capable of immediate readout is required to access "High Radiation Areas" and "Very High Radiation Areas," and when deemed necessary by the ES&H team health physicist.
- ***Portable Survey Meter.*** An appropriate portable survey instrument shall be used for each initial entry into a potentially "High Radiation Area" following operation of a Class IV device (except in the case of pulsed radiation fields) and at other times when the levels of radiation

are unknown. An individual authorized by the safety procedure shall be the first person to enter an exclusion area after device operation.

5.0 LLNL Contacts

For assistance with RGD issues associated with the LLNL Radiation Safety Program, contact your supervisor or ES&H team.

6.0 References and Supporting Standards

ANSI N43.3, "Installations Using Non-Medical X-Ray and Sealed Gamma-Ray Sources, Energies Up To 10 MeV," 1993.

ANSI N43.2, "Radiation Safety For X-Ray Diffraction and Fluorescence Analysis Equipment," 1978.

ANSI N43.1, "Radiological Safety in the Design and Operation of Particle Accelerators," 1978.

Code of Federal Regulation, Title 21, Part 1020.40, "Cabinet X-Ray Systems," 4/10/74.

Code of Federal Regulation, Title 10, Part 835, "Occupational Radiation Protection, " latest edition.

DOE Order 5480.25, "Safety of Accelerator Facilities," 11/3/92; and LLNL's Implementation Plan for that Order.

Letter to Philip Hill, DOE/OAK, from Dennis Fisher dated 10/6/94, RE: Implementation Plan for DOE Order 5480.25, "Safety of Accelerator Facilities."

Appendix A

Terms and Definitions

accelerator

The devices in Table A-1 are defined as accelerators, as required by DOE Order 5480.25.

Table A-1. LLNL devices classified as accelerators.

Device	Energy (MeV)	Located in Bldg.
Pelletron	**1.7**	**190**
Tandem (Van de Graaff)	**10**	**190**
LINAC	**100**	**194**
Pelletron	**3**	**194**
Van de Graaff	**4**	**235**
ETAII	**7.5**	**431**
FXR	**20**	**801**
LINAC	**100**	**851**

beam ports

Openings in a radiation source housing through which radiation is allowed to pass. Collimators, shutters, and filters may be attached to ports to restrict and control the emerging radiation beam.

enclosed beam

All possible x-ray beam paths are fully contained in a chamber, coupled chambers, or other beam-path-confinement devices to prevent any part of the body from intercepting the beam during normal operations. Normal access to the beam path, such as a sample chamber door, must be interlocked with the high voltage of the x-ray tube or the shutter for the beam to be considered “enclosed.” An open-beam device placed in an interlocked enclosure is considered an “enclosed beam,” unless there are provisions for routine bypassing of the interlocks (e.g., for beam alignment).

exclusion area	Any area where a person could receive an effective dose equivalent >5 rem in one hour at 1 m from the source under normal operating conditions.
fail-safe	A design feature built into the system or its components that causes the system to return to a safe condition if a key component malfunctions in its most likely failure mode(s). NOTE: If a fail-safe design is not possible or cost effective, the system and its component should be designed to prevent a single failure from placing the system in an unsafe condition.
high radiation area	Any area accessible to personnel in which radiation exists at such levels that a person could receive an effective dose equivalent between 100 mrem and 500 rads in any one hour when measured at 30 cm from the radiation source.
incidental radiation-generating device	A device that emits or produces x-rays during normal operation, and the radiation is an unwanted byproduct of the device's intended purpose. Examples include scanning electron microscopes, electron pulse generators, and electron beam welders.
intentional radiation-generating device	A device in which particles undergo acceleration in a vacuum to produce x-rays for a particular application. Examples are medical devices, flash x-ray systems, x-ray diffraction and fluorescence analysis equipment, klystrons, laser irradiators, and accelerators.
interlock	A device for precluding access to an area of radiation hazard by either preventing entry or by automatically shutting down the device.
open beam	A device in which the x-ray beam path is not fully contained within a chamber, coupled chambers, or other beam-path-confinement devices during normal operations.
primary beam	Radiation generated from an evacuated x-ray tube that has not been diffracted.

radiation area	Any area accessible to personnel in which radiation exists at such levels that a person could receive an effective dose equivalent between 5 mrem and 100 mrem in any one hour.
radiation-generating device (RGD)	A device that generates ionizing radiation either incidentally or intentionally (including accelerators.)
RGD operator	A person who has met the training requirements for operating the device and is authorized to do so.
RGD safety officer	A health physicist within Hazards Control who is responsible for providing technical guidance on safety issues related to RGDs and coordinating the overall RGD program for LLNL.
secondary beam	Radiation that has been diffracted from a primary beam or is generated by fluorescence.
very high radiation area	Any area in which radiation exists at such levels that a person could receive an effective dose equivalent >500 rads in any one hour at 1 m from the radiation source.

Appendix B: Summary of RGD Radiation Safety Requirements

RGD Compliance Item	Further Explanation	Class I	II	III	IV
RGD Charact/Rad. Safety Eval.	Initially and upon change	X	X	X	X
Inventory- unique RGD #; Class I, II: yearly; Class III, IV: every 6 months	A verbal inventory may be substituted for Class I devices	X	X	X	X
I. Posting					
Notice. Access Control	On entrances to building or area		X	X	X
Caution. X-Ray Area	On doors entering rooms with RGDs		X	X	X
Caution or Danger. Radiation, High, or Very High Radiation Area	Prior to entering radiation field		X	X	X
Caution. RGD Approved Operating Parameters	On control console	X	X	X	X
Class I RGD Guidance Posting	One-page guidance posting near device	X			
Caution. RGD	On tube housing, if applicable		X	X	X
Last Survey Date / Next Due sticker	On control console	X	X	X	X
II. Interlocks, Warning Indicators					
Interlocks					
Key controlled when not in use	Exceptions documented in safety procedure	X	X	X	X
Interlocks, if present are operational		X	X	X	X
Enclosures of fail-safe design			X	X	X
Flash x-ray interlocked during charging	To prevent entry during charging		X	X	
Emergency shutdown switch	Enclosures that can be occupied			(X)	X
Written interlock test procedures			X	X	X
Interlock bypass operations in SP			X	X	X
Master key required to access exclusion areas					X
Redundant interlocks on access doors to exclusion areas					X
Hazard-safe switches at entrances / exclusion areas					X
Key-lock watchman stations or Run-Safe Boxes within the exclusion area					X
Manual reset requirements for interlocks					X
Warning Indicators-Lights					
If warning lights are installed, do not modify		X			
Fail-safe warning lights near source	On, when x-rays are generated or when the machine is being charged. Optional for e-beam RGDs		X	X	(X)
"X-Ray On" or charging status light	Located near console		X	X	
"Shutter Open" lights near shutter	"Shutter Open" lights should be present		X	X	
Lights dimmed prior to operation	In large exclusion areas				(X)
Rotating magenta lights	At entrances to "High Radiation Areas" or "Very High Radiation Areas" during operation		(X)	(X)	X

X denotes "applicable"; (X) denotes "as applicable"

RGD Compliance Item	Description	Class			
		I	II	III	IV
Warning Indicators-Announcements					
Voice announcement to vacate	Audible in large exclusion areas				X
Warning Indicators-Alarms					
X-ray monitor or safety box, or equivalent fixed detector	Adjacent to port if it will enhance safety		(X)	X	
RAM system with remote readout	Visible and audible alarms				(X)
Alarms sounds with radiation generation / evacuation	Chimes / high-pitched chimes				X
III. Shielding & Rad. Safety Survey					
Shielding					
Enclosed Beam Operations					
Dose rate < 0.5 mrem / h at 5 cm	Or a dose rate <100 mrem / y	X			
Dose rate < 0.5 mrem / h at 30 cm			X	X	
Shielding designed to limit dose in occupied areas to < 0.5 rem / y			X	X	X
Beams >0.1 R / h fully enclosed, if feasible			X	X	X
Beam ports covered when not in use			X	X	
Open Beam Operations					
Visible posted barrier at 5 mrem / h, 100 mrem / h, and >500 rads / hr	2 mrem / hr boundary established in accessible areas		X	X	X
Constant surveillance and no operator within visible barrier			X	X	X
Radiation Safety Survey					
"Not Operational" devices, Class I, II: yearly; Class III, IV: every 6 months	Class I devices annual radiation safety surveys may be reduced to a verbal inventory	(X)	X	X	X
IV. Documentation					
RGD logbook	Characterization, surveys, interlock test, and maintenance log. Use log for Class IV devices	(X)	X	X	X
Safety procedure (OSP or FSP)	Bypass operations & all Class II, III , and IV devices		X	X	X
LLNL Implementation for DOE 5480.25	Accelerators, as defined by this supplement only				X
V. Training					
RGD Guidance Posting at device		X			
HS6070 or HS6071, or equivalent			X	X	(X)
HS6911					X
VI. Other Requirements					
Dosimetry					
Whole Body Dosimetry	Neutron dosimetry as required by HP	X	X	X	X
Extremity Dosimetry	As required by the health physicist		(X)	(X)	(X)
Supplemental Dosimeters	Access to "High Radiation Areas"		(X)	(X)	(X)
Portable Survey Meter	Available at work location and entrances to exclusion areas		X	X	X